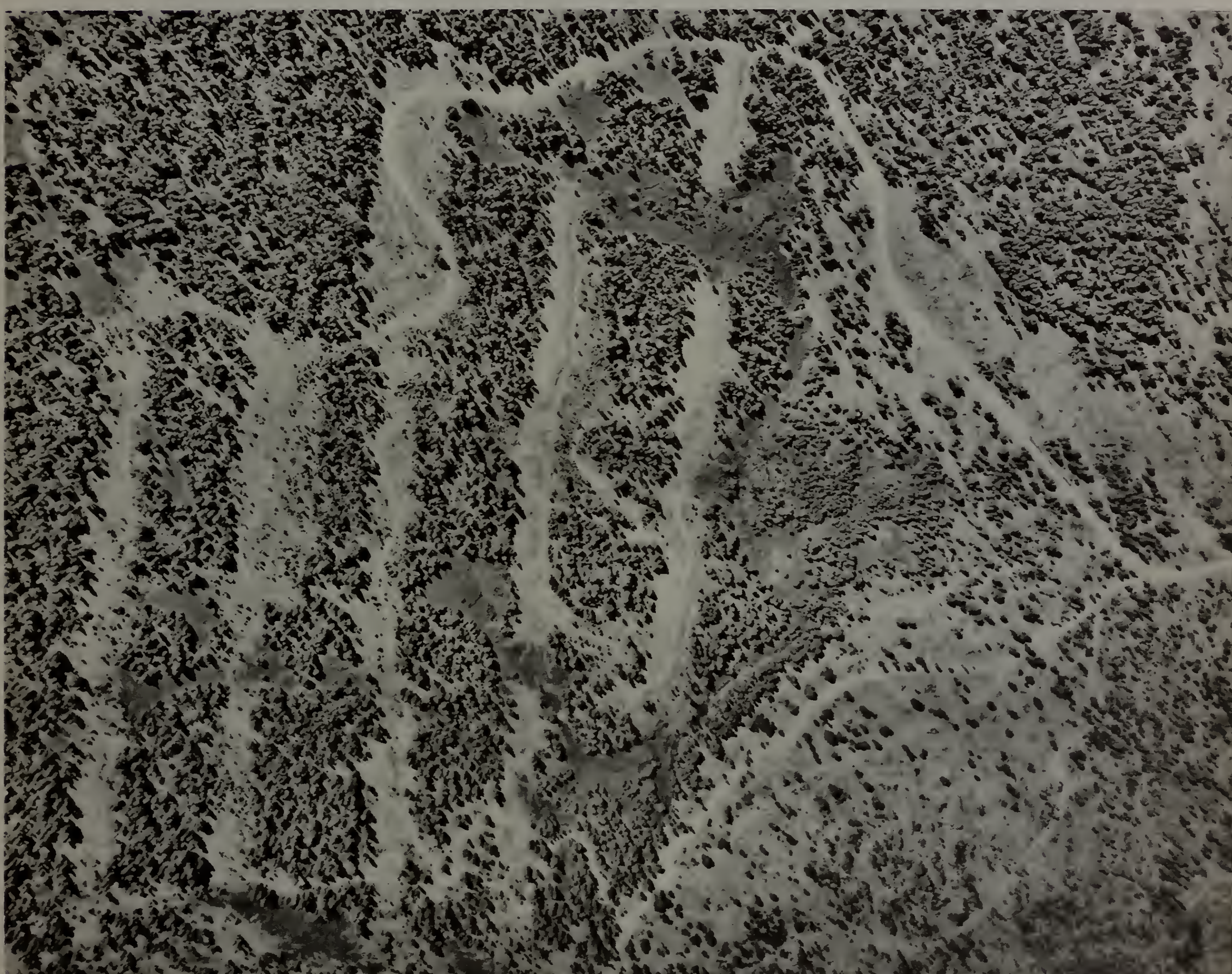
COOPERATIVE SNOW MANAGEMENT RESEARCH



Fifth Progress Report

1961-62 and 1962-63

SNOW STUDY AREAS AND SNOW ZONE IN CALIFORNIA, 1963

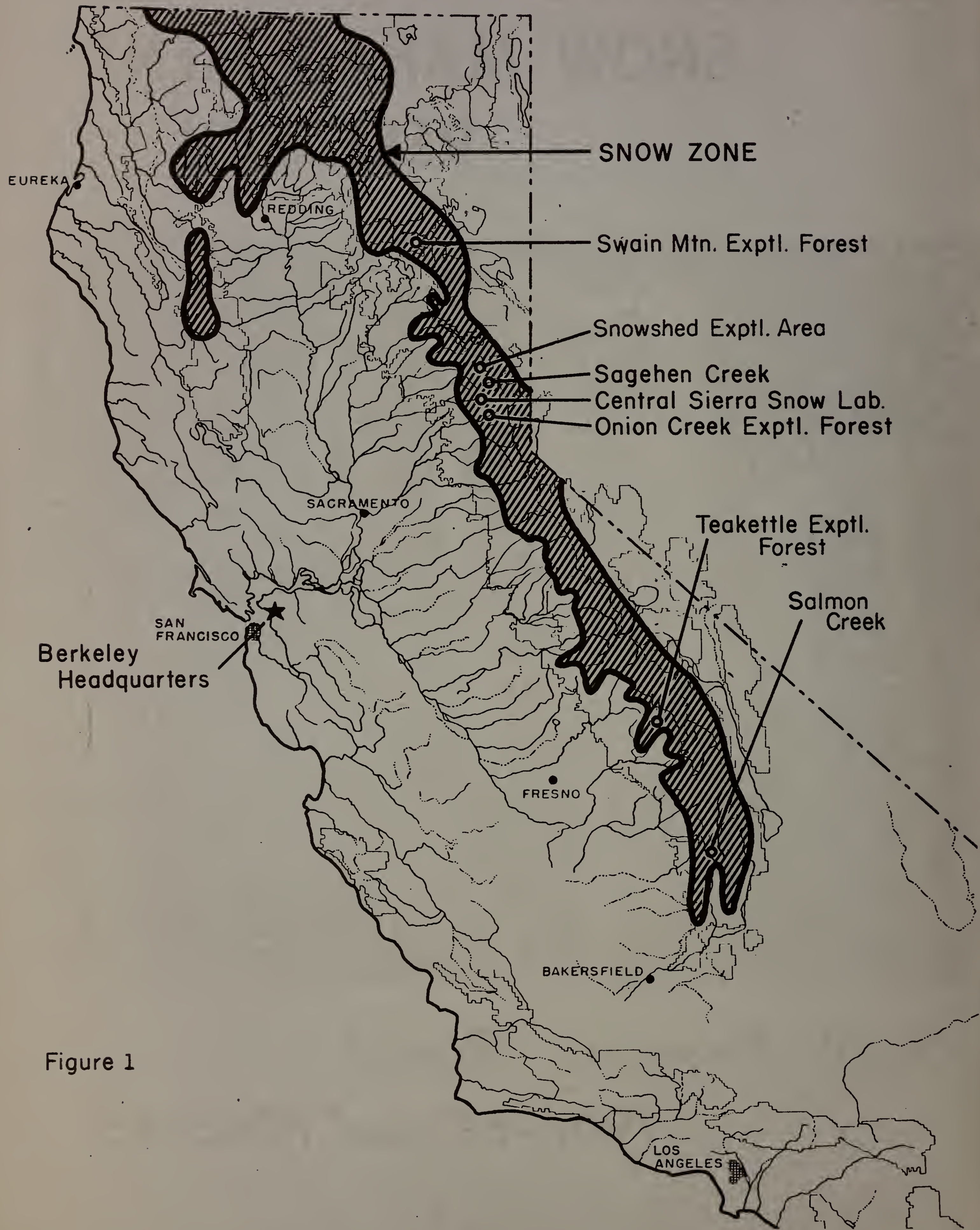


Figure 1

June 30, 1963

FIFTH PROGRESS REPORT

1961-62

and

1962-63

CALIFORNIA COOPERATIVE SNOW MANAGEMENT RESEARCH

by

HENRY W. ANDERSON, LUCILLE G. RICHARDS,
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U. S. Department of Agriculture, Forest Service,
Pacific Southwest Forest and Range Experiment Station

with cooperation of

State of California, Department of Water Resources

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Cover: Aerial photo of logged area at Yuba Pass

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[1] Pages 1 through 56 are contained in the 1957-58 Progress Report, pages 57 through 94 in the 1958-59 Progress Report, pages 95 through 140 in the 1959-60 Progress Report, and pages 141 through 204 in the 1960-61 Progress Report.

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SUMMARY

This is the fifth progress report of watershed management research in California's snow zone conducted by the Forest Service since July 1956 in cooperation with the State Department of Water Resources.

Four formal progress reports precede this report: the 1957-58 report (11) describes the problems, objectives, and methods of the first eighteen studies undertaken, and progress for the first two years of the study. The second report (1958-59) (25), third report (1959-60) (34), and fourth report (1960-61) (51), give individual year progress and objectives and methods for new studies. This report highlights results for the sixth and seventh years of Snow Management Research, and describes two new studies.

Thirteen technical papers and one summary paper were published during the biennium on subjects ranging from "snow evaporation from a forested watershed"to regional appraisal of soil erodibility.

Snow accumulation and melt was measured at snow courses representing conditions of natural forest stands, of forests cut in different patterns, burned over forests treated in different ways, and brushfields, both natural and dozed.

Similarly, summer soil moisture losses were measured at points representing a wide span of forest sites--different slopes, forest conditions, types of logging, methods of slash disposal, and natural and cleared brushfields. The effects of time since logging or brush removal on water loss were evaluated.

Streamflow and sediment deposition measurements were continued in ten experimental watersheds; suspended sediment measurements were taken at some forty places, including logged and unlogged watersheds, burned and logged watersheds, unburned watersheds, and watersheds being calibrated for future treatment.

Of significance were the first results of tests of methods designed for maximizing snow accumulation and melt by special cutting patterns and logging slash treatment. The methods are apparently even more effective than predicted from previous basic studies.

The biennium was characterized by a year of average snowpack and runoff, 1962, followed in 1963 by a year of light, late snowpack preceded by two major rainstorms that brought flood flows and total runoff of above average amounts.

Plans for the coming year (July 1963 through June 1964) are to concentrate on analysis of the data accumulated and to appraise the

effectiveness of the emergency treatments of burned-over watersheds, to evaluate the cutting patterns and slash treatments, to further test chemical control of evaporative losses, and to design treatments to be applied on experimental watersheds. We plan to complete the regional appraisals of flood and sediment sources, soil erodibility, and the present water yield, and determine their relation to forest and other wild land conditions which might be subject to management. Continued emphasis will be placed on analyzing the past data thoroughly, keeping analysis of new data as current as possible, and publishing results.

Financing and excellent cooperation in the project have made possible rather satisfactory progress. The State's contribution through the Department of Water Resources for the research is now $65,000 per year. The Forest Service matched this amount and conducted the research. Other agencies continue to lend a hand: Pacific Gas and Electric Company, Fibreboard Inc., the Weather Bureau, the U. S. Geological Survey, the Department of Zoology of the University of California, and the Tahoe, Sierra, and Sequoia National Forests.

Reprints of published papers are available, and other information is available upon request. To make this information more accessible, a detailed index has been included as part of this report. Inasmuch as this is a continuation of previous progress reports, page numbers start with 205.

FIFTH PROGRESS REPORT, 1961-62 and 1962-63

CALIFORNIA COOPERATIVE SNOW MANAGEMENT RESEARCH

by

Henry W. Anderson, Lucille G. Richards, and Minnie E. Groshong

INTRODUCTION

Since 1956, research has been under way on the hydrology of California's snow zone, and particularly on the effects of land use and land management on water yield, floods, and sedimentation. The studies are being made by the Pacific Southwest Forest and Range Experiment Station of the U. S. Forest Service, with the cooperation of the Department of Water Resources of the State of California. Assistance of various kinds has been provided by the University of California, U. S. Weather Bureau, U. S. Geological Survey, Fibreboard Corporation, and the Pacific Gas and Electric Company.

Snow Management Research aims to add to the present body of knowledge of the role of the snow zone in the future water supply for the state; further, the physical consequences to the water supply of alternative methods and techniques of management of the land and the forests of the zone are being studied.

This is a report of progress during the biennual period 1961-62 and 1962-63 in each of 21 studies now under way and an outline of objectives and methods for four studies started since June 1961. The objectives of the first 22 studies that have been conducted, the methods used in each study, and the results to date have been outlined in previous progress reports (11), (25), (34), and (51), and in some 53 other formal publications and 23 file reports. (See pages 225-231). This report will concentrate primarily on reporting results during the past two years, and appraising the status of the studies in the light of the objectives.

KINDS OF STUDIES

The studies are of four kinds:

1. Inventories of present conditions of:

Water yield	(Study No. 1-10)
Land conditions	(Studies Nos: 1-1, 1-5)
Soil erodibility	(Study No. 1-18)

2. Studies of basic meteorology, snow, and heat balance (Studies Nos. 1-4, 1-6, 1-7, 1-9, 1-11 in part, 1-13, 1-14, 1-15, and 1-23).

3. Development and testing of methods of improving water yield and controlling sediment (Studies Nos. 1-8, 1-11 in part, 1-16, 1-19, 1-20, 1-22, and 1-25).

4. Pilot tests of various forest and land management methods on experimental watersheds for their effects on streamflow and sedimentation (Studies Nos. 1-2, 1-3, 1-12, 1-17, 1-21, 1-24).

Detailed plans of these studies, data collected, summaries, and reports are available for inspection upon request.

The study areas are shown in Figure 1 (inside cover). Location of the individual study sites has been given in the previous progress report (51).

INDIVIDUAL STUDIES

Inventory of Sierra Hydrologic Characteristics (Study No. 1-1)

The original objective of this study was to determine what land and topographic conditions required research, how much land would be subject to management for improved water yield, and where treatments for water yield improvement would be most effective. Results of this study have been summarized by Richards (26 and 41). Further evaluations of hydrologic characteristics are being carried on under three studies: water yield (1-10), sedimentation (1-18), and flood sources (2-2)[1/].

Performance of Onion Creek Experimental Watersheds (Study No. 1-2)

In the headwaters of the American River, streamflow and sedimentation have been measured in five small watersheds for five years. Three of these years were in the drought period, 1959-1961, one was the moderate year of 1962 and one was the heavy year of 1963.

1/ The flood study (2-2) was originally started as a Lower Conifer Zone study but has now been shifted to the Water Source Hydrology Unit.

Annual flows of these watersheds for the two years, 1961 and 1962, together with maximum discharges for those years, are given below:

Watershed No.	Drainage Area	Maximum Discharges 1961	Maximum Discharges 1962	Annual Flows 1961	Annual Flows 1962
	sq. mi.	cfs/sq. mi.		inches	
1	0.10	11	22	13.7	26.2
2	0.48	16	33	17.3	31.4
3	0.65	10	20	15.7	28.4
5	0.39	32	28	22.4	33.5
7	0.80	14	24	16.1	28.2

Daily discharge records for the five watersheds for the years 1960 and 1961 are published in the U.S.G.S. Water Supply Paper No. 1715 and U.S.G.S. Surface Water Records for California, vol. 2, 1961. Provisional daily discharge records for all watersheds for the year 1962 are available upon request.

Again this year suspended sediment was automatically measured at weir #3, to obtain an estimate of the sediment outflow from the reservoir.

Plans--The plans are to continue streamflow and sedimentation measurements in the five watersheds until calibration is achieved.

Streamgaging and Sediment Measurements at Teakettle Experimental Watersheds, Kings River (Study No. 1-3)

Streamflow and sedimentation were measured at another set of five small watersheds in the snow zone of the southern Sierra (Figure 1). Maximum discharges and annual flows for the years 1961 and 1962 are given below:

Watershed No.	Drainage Area	Maximum Discharges 1961	Maximum Discharges 1962	Annual Flows 1961	Annual Flows 1962
	sq. mi.	cfs/sq. mi.		inches	
1	0.77	7	12	5.04	20.2
2A	0.27	7	10	3.48	17.5
2	0.85	4	8	4.22	17.3
3	0.86	7	12	5.36	18.9
7	0.09	4	48	4.52	1/ 28.6

1/ Probable change in watershed area in 1962 to be field checked.

Daily discharges for the year 1960 and 1961 for all watersheds are published in U.S.G.S. Water Supply Paper No. 1715 and U.S.G.S. Surface Water Records for California, Vol. 2, 1961, respectively. Provisional daily discharges for the water year 1962 are available upon request.

Suspended sediment inflow and outflow from the reservoirs were measured, using automatic, suspended sediment samplers.

A system of roads will be installed on the Teakettle area following calibration to evaluate the effects on streamflow and sedimentation. Installation is tentatively planned for the summer of calendar year 1965. The roads in each of the Teakettle watersheds have been designed to accomplish specific water management objectives: (1) to maximize water yield, road surfaces in one watershed are to be drained inward to the ditch and the water is then led to the stream channels, (2) to delay water yield especially in dry years, infrequent overside drains in another watershed will lead road water across fills to areas of deep, permeable soil and rock, with the water in channels being detained in ponds made by the road fills, (3) to minimize floods and sedimentation, road ditches drain toward the ridges and road fills are equipped with drop inlets that catch sediment and decrease the rate of flood runoff.

Plans--Measurements will be continued and detailed study plans drawn up for the satellite studies to the road program.[2/]

Cooperation--The Pacific Gas and Electric Company has generously cooperated in servicing these Teakettle gaging stations during the winter months.

Inventory of Forest Conditions at the Central Sierra Snow Laboratory Snow Courses (Study No. 1-4)

This study is complete. Any further studies of the evaluation of forest conditions will be carried on under Study No. 1-11.

The results of these studies have been published in three papers (1, 6, and 14).

Plans--We plan to encourage graduate students to make more detailed analyses of the wealth of data on snow accumulation and melt, and the highly detailed measurements of forests made at these snow courses.

Soil-Vegetation Surveys of Castle Creek Laboratory Basin (Study No. 1-5)

This study is complete. The results were published in publication number 5, and summarized in publication number 34, pages 122

2/ Plans for all studies except 1-1, 1-10, 1-11, and 1-18, reflect the thinking of James L. Smith, the Snow Project Leader as of July 1, 1963.

and 124. Summaries from this study of forest conditions by topographic position are given in publication number 42.

Basic Meteorological and Snow Measurements, Central Sierra Snow Laboratory (Study No. 1-6)

Basic meteorological and snow studies this year were routine except for studies under other formalized headings.

Meteorological and snow records have been taken in and near the Central Sierra Snow Laboratory since the program began in July 1956. The records taken and the status of data processing are summarized in table 1, appendix A. All records have been microfilmed and Kardex referenced. Daily temperature, precipitation and snow records for the CSSL headquarters for the period July 1961 through June 30, 1963 are given in figures 2, 2a, 3 and 3A, Appendix B. Daily precipitation for the years 1961 and 1962 are given in tables 2 and 2a, Appendix A. Monthly summaries of temperature extremes, precipitation and snow for the two years are given in tables 3 and 3a, Appendix A.

Cooperation--The Weather Bureau has cooperated in these studies by taking wind direction and velocity measurements for us at their Blue Canyon Station, 20 miles west of the Laboratory at an elevation of 5,000 feet. We in turn are supplying daily meteorological, snow, and streamflow data to them. This data is used in the State Flood Forecasting Service. Water and air samples, for radioactive determination by the State Department of Public Health, have been taken at their request.

Plans--We are evaluating our future needs for meteorological data. Some old stations may be dropped and some new ones added to our network.

Wind Effects on Snow Accumulation in the Forest (Study No. 1-7)

This study was inoperative during the year; no immediate plans for continuation of this study have been drawn.

Hydrologic Processes and Erosion Measurements (Study No. 1-8)

Summer soil moisture loss and snow accumulation and melt were measured in a logged area, unlogged area, in a power line clearing, and in a brushfield (sites A-E, and T1 and T2, Fig. 5, Paper No. 51). The logging was a commercial diameter-limit cut, in which all trees greater than 18 inches in diameter were removed. Comparisons of final summer soil moisture storage in cut and uncut old-growth red fir forests at an elevation of 7,000 feet for the first five years

after logging are shown below:

Treatment	Dates				
	Nov.2,1958	Sept.2,1959	Sept.15,1960	Sept.8,1961	Aug.16,1962
Logged	8.25	7.34	6.60	6.86	8.96
Unlogged	6.33	6.12	5.56	6.12	8.11
Saving	1.92	1.22	1.04	0.74	0.85

We see that in this area which was selectively cut the savings in soil moisture were rather small, even the first year after logging, and these declined with successive years as roots invaded the cut areas.

The effects of the above logging on snow accumulation and melt are shown for the years 1961 and 1962 below.

Treatment	Dates				
	Dec.22,1960	Jan. 12,1961	Feb.28,1961	Apr.5,1961	May 2, 1961
Logged	12.3	11.8	17.2	20.7	12.3
Unlogged	8.8	8.4	9.8	12.9	9.0
Difference	3.5	3.4	7.4	7.8	3.3

Treatment	Dates		
	Feb.2,1962	Mar.27,1962	May 25,1962
Logged	13.0	46.8	7.2
Unlogged	9.0	41.4	10.6
Difference	4.0	5.4	-3.4

The contrast between the light snowfall year of 1961 and 1962 is quite apparent. In 1962, although accumulation in the logged area was only about five inches greater than in the unlogged area, melt was more rapid in the logged area so actually more water was stored in the unlogged area late in the spring than in the logged area.

To serve as a contrast to the commercial diameter-limit cutting method, two transects were established across a power line strip clearing (51, page 150). The power line clearing was established 10 years ago, then widened five years later. The following tabulation indicates, for the two ages of cutting and the adjacent uncut forest, final soil moisture storage on August 30, 1960 and the saving of water resulting from the cutting.

Forest Age years	Final Soil Moisture inches	Saving inches
5	9.4	3.0
10	7.6	1.2
old growth	6.4	---

We see considerably greater savings in the strip cut than in the commercial selection and a longer persistence of the saving in soil moisture as a result of the cutting. (See also Ziemer's results reported under Study 1-19).

Persistent snow accumulation also resulted from cutting in strips as indicated by snow in the powerline transect: the part of the strip cut five years ago had 13 inches more snow than the adjacent forest; the part cut 10 years ago had 10 inches more snow than the adjacent forest.

Variations in soil moisture storage at the end of summer at the Onion Creek brush plots (3-foot soil) for the five years of study are shown below:

Site	Soil Moisture Storage - Inches 1/				
	9-25-58	9-1-59	9-15-60	9-11-61	8-20-62
Block C, level ridge	4.9	4.0	3.7	3.8	4.6
Block D, 24% W slope	4.8	3.8	3.5	3.6	4.0
Block E, 21% SE "	4.8	3.7	3.5	3.6	4.0
Average	4.8	3.8	3.6	3.7	4.2

1/ Field water holding capacity is 9.0, 9.7, and 8.3 inches for C, D and E

It appears from the consistency among these final soil moisture storages that these plots should now be considered calibrated sufficiently so that treatments may be applied for evaluation of savings as a result of brush treatment.

Plans--The plans are to further study the soils of the area and to examine possibilities for treatment of the brush for moisture savings. Soil moisture regime in the cut and uncut forest seem to be sufficiently outlined for the present so these measurements may be discontinued. (Variability in the snow performances in this cut and uncut forest might make it worth while to continue these measurements for another year or two.)

Basic Meteorological and Snow Measurements, Teakettle Experimental Forest (Study No. 1-9)

Again this year the Pacific Gas and Electric Company made regular weather observations and measurements for us at the station near Wishon Dam. These measurements are proving useful in working up the streamflow measurements at the Teakettle watersheds and will serve to characterize the years of study in these watersheds.

Plans--We plan to ask the Pacific Gas and Electric Company to continue the meteorological measurements at Wishon Dam; these measurements are needed for the analysis of the streamflow records.

Water Yield (Study No. 1-10)

This study is still in the data collection phase. For this study and studies of sediment and flood sources in northern California, watershed physical characteristics and watershed cover conditions and land use are being collected. For 500 study watersheds, fire histories have been compiled for the 20-year period, 1940 to 1959; the amounts and characteristics of the present vegetation in each watershed are being taken from aerial photographs, together with estimates of the amount and characteristics of the logged-over areas (typical outputs are from the IBM tabulations of these vegetation characteristics for the Sacramento River at Delta watershed, shown in table 4, Appendix A.)

Plans--We intend to push this analysis toward completion by June, 1964.

Heat Equivalent and Snow in Forest Openings and Forest Slopes (Study No. 1-11)

Following the water year 1961 the number of snow courses measured under this study was reduced from approximately 100 to 17 snow courses.

Data from 58 to 66 snow courses have been analyzed to provide some answers to how snow measurements in and around forest openings may be interpreted. The question, "What portion of the increased snow found in openings is a true increase rather than a mere redistribution of the total snow supply? " has been studied. The tabulation below allows comparison of average snow courses in forests having openings as part of the site in two widely different years:

Site	Snow at Maximum Pack inches (water) 1958	1959
In forest near openings (1-1/2 area of opening)	56.0	22.6
In opening (average all sizes)	63.2	26.3
Within forest, 35% density	57.0	23.2
Within forest, 50% density	53.4	21.5
Within forest, 90% density	48.1	15.8
Opening, associated snow (opening plus extra snow surrounding)	67.1	29.0

We see that only about one-half of the difference between the forest and cut opening (e.g., 67.1 - 53.4 = 13.7) is found by comparing openings and adjacent forest (e.g., 63.2 - 56.0 = 7.2). Note that this is contrary to some interpretations, that openings exaggerate the difference between cut and uncut areas. Drought year management effects may be interpreted from the 1959 data. Cutting openings increased snow storage about 35 percent (compared to the 50 percent forest) in the drought year of 1959, whereas it increased snow only 26 percent in the near maximum year of 1958. In contrast, the selection cutting is quantitatively much less effective even if we reduce a 90 percent dense forest to 35 percent density. However, we would get nearly as great effect in the drought year, 34 percent increase, but only a 17 percent increase in the very wet year of 1958.

Plans--Further analysis of data collected in this study is planned.

Streamflow and Sediment Measurements, Castle and Salmon Creeks (Study No. 1-12)

The daily streamflow hydrographs for Castle Creek for the years 1961 and 1962 are shown in Figures 4 and 4A. Streamflow and sediment production in the watershed in these years were influenced by the construction of a freeway (No. 51, page 201). A slum dam was installed above the gaging station to catch the heavy debris, which

might interfere with the flume and weir at the present gaging station. Streamflow measurements and suspended sediment samples of representative flows were taken throughout the years.

Average suspended sediment concentration in the runoff year of 1962 was 212 ppm; this is about three times the concentration which would have been expected without the construction of the freeway. There is no evidence that the freeway construction has increased the yield of water from Castle Creek in 1962. In contrast to the years 1959 and 1960 which had higher discharges, associated with logging in the watershed, the year 1962 is below the trend line (Onion Creek No. 1 used as a control).

In an effort to determine the sources of the large increases in sedimentation following the logging of Castle Creek, Rice and Wallis (49) made a detailed study of the sources of sediment. Erosion from roads and landings which were part of the logging operation was the source of most of the sediment. Minor drainages were often diverted down logging roads, causing the removal of all fine material. Landings made by building fills across stream channels now have deep V-notched gullies across them. These landings have been an obvious source of increased sediment. Rice and Wallis concluded that "even though the total disturbance of the Castle Creek watershed was not great, the location of roads and landings created a large sediment source. More attention to water values could have eliminated much of this source."

On the Salmon Creek Watersheds (Kern River Basin), another watershed was instrumented this year, bringing the total to three small watersheds that are in operation. The study is being made in collaboration with the Sequoia National Forest, whose personnel installed the weirs and cutoff walls.

Plans: Streamflow measurement in the Salmon Creek Watersheds will continue, probably with the direct cooperation of the U.S.G.S. Plans for Castle Creek where the flume was destroyed by the January 1963 flood will depend on what salvage of record and restoration of gaging is possible.

Winter Evapotranspiration in Relation to Forest and Terrain Characteristics (Study No. 1-13)

Measurements of evaporation from snow this year were made in connection with the study of effect of hexadecanol on snow evaporation. These will be summarized under Study No. 1-22.

Published data on the interception of snow were examined by Miller (54) to appraise what is now known of how much water--water or vapor--arrives at several destinations and how that water gets there:

by snow drifting, falling, blowing, sliding from the trees, and dripping to the ground.

Plans--Study of winter transpiration is the next important field needing investigation. The use of heat transfer technique in woody stems seems a promising approach to at least comparative measurements (Skau and Swanson in report to the American Geophysical Union, 1963).

Heat balance components in forests and openings (Study No. 14).

Field progress in this study has consisted mainly of the testing of a variety of instruments available for measuring shortwave and longwave radiation. Problems and sources of error in measurement of radiation were outlined by Miller (File Report No. 17).

Plans--We plan to complete the instrument testing and then measure the radiative heat components in a variety of forest conditions.

Evaluation of Summer Evapotranspiration in Relation to Forest Sites (Study No. 1-15)

Field measurements under the initial purpose of this study have been completed. These sites have continued to be used for other tests such as treatments on water losses (Study No. 1-22). The indications are that by use of these calibrated sites we are able to evaluate differences in summer water losses in the order of 0.1 to 0.2 inches per year (where total loss ranged from 4.0 to 8.0 inches).

Plans--We intend to encourage further use of this data in analysis of the relationship of physical soil conditions to evapotranspiration. DeBano has made a thorough search of the literature and has outlined the elements of a model for such evaluations.

Swain Mountain Snow and Soil Moisture Studies (Study No. 1-16)

Field measurements under this study have been discontinued for a period of years to allow time shifts in the measurements to reach significant differences.

Plans--After a period of perhaps five years, re-measurement of snow accumulation and melt and soil moisture losses may be desirable at these sites to evaluate how the relationships have changed with time.

Sagehen Cooperative Study of Streamflow, Sedimentation, and Fish Habitat (Study No. 1-17)

Part of the study in this area is evaluation of the effects of conversion of brush fields to pine on the snow accumulation and upon soil moisture losses. Measurements of soil moisture depletion

have been made now for five years following the bulldozing and planting of an area to pine, (51, page 203, plots F, G, and H). Differences in final soil moisture storage in the soils for three depths, three, four and five feet, are summarized in Table 5. Notice that for all depths, savings in soil moisture associated with the dozing declined each year; for example, from approximately five inches in the five foot soil in the first year after dozing to 0 inches saving the fifth year after dozing. Brush sprouts from the root crowns left after the dozing have noticeably invaded the site. The young pines are growing vigorously; however, the old established roots of the brush are probably the major users of water. Spraying of the brush with an herbicide could easily produce evidence on this point.

Parts of these plots (F, G, and H) have also been used to test the effects of hexadecanol on summer water losses (Study No. 1-22). Suspended sediment sampling has continued at Sagehen Creek this year; through the cooperation of the U.S.G.S., water quality analyses were made of some of the samples. Results of this are reported under another study (Study No. 1-21).

Plans--Further use of the calibrated brush sites in testing other treatments for their effects on soil moisture are suggested, including the use of herbicide sprays on the brush sprouts in the bulldozed plots to test the effects of this on reductions in soil moisture losses.

Erodibility of California Wildland Soils, Relation to Sedimentation (Study No. 1-18)

Because of encouragement from early studies of the relationship of erodibility of California wildland soils to mapable characteristics of geology, topography, and cover type, these studies have been expanded. More samples were taken throughout the wildland areas of northern California, bringing to 258 the number of samples of soil which have been taken.

Soil samples have been analyzed in the laboratory to include not only measures of soil erodibility but also texture classes and organic matter. A 1620 computer program for these analyses has made possible rapid calculations involving more than 80 separate arithmetic operations.

Analyses of these data have related soil erodibility and soil texture to some 12 individual rock types of northern California, to forest vegetation types and to some specific expressions of climate--precipitation amount and temperature. Through these analyses some interesting and important relationships to hydrology of the wildlands are being appraised (Wallis and Willen, 1963).

In another detailed study at the Teakettle Experimental Forest, variation in soil texture and erodibility developed under different slopes, elevations, vegetation types, and geology has been determined (Willen, 1963). Willen found that soils developed under Olivine basalt were less erodible than soils developed from quartzite and granodiorite; fir soils were less erodible than those under pine, brush, or grass types; soils of east aspect tend to be less erodible than those on north, south, or west. Soil texture development was significant when related to both elevation and slope, in that particle sizes, both of clay size and larger than sand, decreased with elevation; total clay, and particle sizes larger than sand, decreased with increase in slope from 20 to 40 percent. Erodibility tests showed that these high elevation soils (7,000-8,000 feet elevation) were approximately two times as erodible as soils on similar rock types at elevations of 2,000 to 4,000 feet.

In assembling the watershed information pertinent to this and other regional analyses, some methods and techniques of importance to hydrology have come out as a side product: a rapid method for getting area-elevation information has been developed (55); and some improved methods of appraising stream drainage composition proposed (File Report No. 19).

Plans--We plan to utilize the results of these studies in erodibility in the further analysis of sediment sources and sediment causes in California's wildlands, utilizing the available data on suspended sediment and reservoir deposition, to relate sediment discharge to its sources and total sediment delivered to the cause variables acting on the watersheds.

Summer Water Losses as Related to Time Following Logging and Associated Vegetation Recovery (Study No. 1-19)

In this study, started in July 1960, the time since logging as a factor in determining summer water loss was appraised by studying openings created by logging from one to 12 years ago. On high elevation sites in the Sierra Nevada, soil moisture savings in the openings persisted for nearly 16 years, starting at seven inches the first year after logging and becoming zero at the sixteenth year. Total savings over the period in the logged area amounted to 34 inches or approximately three acre-feet of water per each acre logged. (Details are given in a MS thesis by Ziemer and in File Report No. 16).

In these areas of deep snowpacks, where snow covers small trees and lower branches of large trees for long periods of the year, winter savings following logging would persist even longer than these summer soil moisture savings. (See Powerline Transect results, Study 1-8).

Plans--The original purpose of this study has been accomplished. These sites may be suitable for treatments which might affect water yield and also suitable for evaluation of the effects of time since logging on snow accumulation and interception.

Yuba Pass Tests of Logging and Slash Treatment Effects (Study No. 1-20)

By the end of the 1962 logging season this practical-sized test of logging and slash treatment methods was approximately 75 percent complete. Details of objectives and treatment are outlined in Paper No. 34, pages 113, 114. To evaluate the effectiveness of these alternative methods of treatment for water yield improvement, five snow course transects, with a total of about 400 points, have been established and first measurements taken. Peak stage indicators and automatic suspended sediment samplers have been put on minor tributaries within the sale area to evaluate effects of alternative treatments. The collaboration of the Tahoe National Forest personnel in advertising this special treatment site for sale and helping our men, West and Adams, in getting the treatment applied on the ground, was a major factor in the success of this trial. First results indicate that the so-called "ideal forest cutting" for snow accumulation may be even more effective than had been predicted from previous basic studies, a 65 percent increase in the snow in the cut strip over the uncut forest was indicated, with a 20 percent increase in the "first step" to the north of the cleared strip.

These are some of the first results of snow measurements on April 24, 1963--about the time of maximum snow accumulation:

1) The middle 1/3 of the uncut forest between cut strips had the same amount of snow as the precut forest, 18.2 to 20.9 inches (average 19.0).

2) Where an "extra lane" was cut the "middle" forest had about 1.1 inch more snow than before.

3) Where sample strips were clear-cut the usual excess of snow to the windward and deficit to the leeward side of the opening occurred. The effect of this particular 4-cycle cutting may be expressed in two ways: as its effect in change in snow accumulation per unit of cut area, or its effect on average snow in the whole forest. On April 24, 1963, with snow in the forest of 19.0 inches, these additional amounts of snow were brought about by the different strip cuts:

Area	Excess of Snow Associated with Treatment				
	Slash Piled	Slash Lopped	Residual Stand	Slash Dozed Down	Wall-Step[1/]
	inches				
Cut Area	4.4	6.4	8.0	14.4	18.9
Whole Forest	1.1	1.6	2.0	3.6	4.7

1/ In wall-step cutting 1/4 of stand was clear cut, 1/4 was partially cut (largest trees removed), and 1/2 was uncut; in others only 1/4 of stand was clearcut, except in one where the residual stand was left.

We see that the wall-and-step cutting (actually combined with slash dozing to down-hill margin of the clear-cut) nearly doubled the snow accumulation. Dozing the slash downhill was nearly as effective. The other forms of treatment were less effective.

4) The location of the snow water increase in the wall-and-step forest was about 60 percent in the clear-cut strip and 40 percent in the other areas:

Position	Increase over uncut forest
	inches
Forest margin to south, 133 ft. wide	2.0
East-west cut strip, 133 ft. wide	10.8
Partial cut forest to north	5.0
Center of uncut forest	1.1
Total	18.9
Average	4.7

The increase in snow water in the forest as a whole of 4.7 inches with removal of only about 40 percent of the volume is impressive.

Plans--The plans are to keep this study and analysis current and to make observations on the recovery of vegetation.

An Evaluation of Forest Fire, Salvage Logging, and Watershed Treatment on Floods and Sedimentation, Snow Accumulation, and Soil Moisture Losses (Study No. 1-21)

This is a study of the emergency treatment of the Donner Ridge burn of August 20, 1960, which occupied some 39,000 acres in the headwaters of the Truckee River basin. Water quality evaluation was added to the study in 1961, with the cooperation of the U. S. Geological Survey. Details of the study are included in Paper No. 51 (pages 162 and 163).

The first year after the fire was one of very light precipitation and snowfall. Runoff and sediment production in that first year were trivial, except in the eastern edge of the burn, where a thunderstorm in September caused major flooding and sediment production in watersheds which had been untreated (Copeland and Croft, Journal Geophysical Research 67, page 1633, 1962).

Tests of differences in water quality in burned and unburned segments of this study area, showed few differences in that first year of small runoff.

Major storms in October of 1962 and January of 1963 produced significant runoff and sediment production, which should permit evaluation of the effects of the alternative treatments on these phases of the water problem. Soil moisture measurements have been taken and five inches more soil moisture storage in the burned areas than in nearby unburned forests were found at the end of the summer.

Plans--The plans are to analyze the data to see if study objectives have been met.

Cooperation--The Tahoe National Forest is collaborating by conducting all the treatments on the watersheds. The Fibreboard Corporation is cooperating by making requested treatments on their lands and in other ways. The U. S. Geological Survey is cooperating by analyzing the water quality samples. The University of California, Department of Zoology, is cooperating by continuing the sediment measurements at Sagehen (one of the controlled unburned watersheds), and furnishing basic meteorological records from their Sagehen Headquarters.

Evaluation of Hexadecanol as an Evapotranspiration Retardant (Study No. 1-22)

In the 1961 test we applied hexadecanol in mid-summer as a water emulsion to the soil surface of bare soil sites, to the forest floor at red fir forest sites, and to vegetation and soil at brush and herbaceous sites. One inch of water was then sprayed on the site to flush the hexadecanol into the soil.

In 1962 tests, hexadecanol was applied to the snow late in the melt season, or where snow was absent; it was applied to the wet soil and nearby snow was shoveled onto the site to a depth of about six inches.

In all, 14 natural sites ranging in size from 1/30th to 1/15th acre were treated at the rates of 35, 135, or 680 pounds per acre. Similar sites in all cases were untreated. Experimental controls consisted of "test" and "control" sites measured for three years before treatment and during the years after application of hexadecanol.

Only in the bulldozed brush field and in the site with heavy application of hexadecanol under snow did significant reductions in evapotranspiration occur with the application of hexadecanol. In the bulldozed brush field savings were two inches the first year after an application of 130 pounds hexadecanol per acre and one-half inch saving the second year. At a single red fir site where the heavy, 680 pounds per acre, application of hexadecanol was applied and snow shoveled onto the site, a reduction of three and one-half inches in the water loss occurred the first summer after this treatment. Lesser rates of application of hexadecanol under similar circumstances failed to show appreciable effects.

Snow evaporation was markedly affected by applications of emulsion of hexadecanol at the rate of 12 pounds per acre to the snow surface. Reductions range from as little as 13 percent under a dense forest stand to as much as 70 percent in open areas.

Plans--We plan to make spot-checks of the effect of hexadecanol on sites in which hexadecanol was applied to the soil or vegetation. We plan to continue to test the effects of hexadecanol and other evaporation suppressants on snow to evaluate the duration of these effects.

Cooperation--The Proctor and Gamble Company is cooperating by furnishing the hexadecanol for these tests; the Tahoe National Forest is collaborating by furnishing available spray equipment and contracting with the cooperators for the use of other equipment.

Use of Radioactive Isotopes in Measurement of Snow Density Profiles (Study No. 1-23)

Use of radioactive probes inserted in mountain snowpack promises to make possible more accurate appraisal and prediction of snowmelt runoff. Available gamma and neutron probes were tested for their ability to measure snow density, ice lenses, and thermal quality of individual layers in the snowpack (No. 56).

Snow density (determined gravimetrically) ranged from 12 to 60 percent. Usable regressions of snow density (D) with neutron counts (Cn) and gamma counts minus 5,000 (Cg) in CPM have been found. Improvements in the regressions were obtained by using the counts above and below as well as at the measurement depth. Counts 6 inches above (Cna or Cga) and 6 inches below (Cnb or Cgb) as well as the counts at the point were used. For Gamma probe at depths >18 inches, $D = 11.8 + 0.022\,Cg^2 - 0.722\,(Cga - Cg) - 1.03\,(Cgb - Cg)$; for depths of 12 inches, $D = -2.7 + 1.25\,Cg + 0.50\,(Cgb - Cg)$; and for depths of 6 inches, $D = -2.6 + 1.33\,Cg + 1.39\,(Cgb - Cg)$. Standard errors of estimates were 3.5, 2.3, and 3.5.

percent. For the neutron probes at depths $\geq$ 12 inches, $D = 9.1 + 6.25\ Cn - 0.052\ Cn^2$; and for depths of 6 inches, $D = 2.2 + 12.3\ Cn - 1.00\ Cn^2 + 2.9\ (Cna - Cn) + 11.2\ (Cnb - Cn)$. Standard errors of estimates were 3.6 and 2.2 percent. Counts in water for these probes, with aluminum access tubes were 15,900 and 44,400 CPM for the neutron and gamma probes, respectively.

Can the probes help detect the time when the spring snowpack will start to melt and predict the rate of melt? Some preliminary tests indicate this is a distinct possibility. The rate of melt of spring snowpacks has been found to vary widely from year to year, even when the melt is expressed in terms of the amount of heat rather than time alone. The problem may be expressed as: how many degree days will be required before the melt of the pack starts and at what rate does the pack melt per unit of degree day after the start? By comparing three conditions which had widely different snowpack characteristics early in the spring (April 3-7, 1962), the lag in the initiation of melt and the rate of melt in those three conditions were found to be related to the neutron and gamma count profiles in the snowpack.

Spring snowmelt at three sites as related to neutron and gamma counts at the top and bottom of the snowpack, Central Sierra Snow Laboratory, elevation 7500', 1962

Condition	Neutron counts		Gamma counts		Lag in melt	Melt rate
	Top	Bottom[1/]	Top	Bottom[1/]		
	- - - - - - - 1,000 CPM	- - - - - -			Degree Days	In./degree day
Open	5.2	6.0	39	43	60	0.15
Shaded	3.5	6.0	35	43	90	0.11
Forest	3.5	5.8	35	43	130	0.10

1/ One foot from top and bottom of snowpack.

Note that the bottoms of the snowpacks were remarkably uniform for both gamma and neutron counts. However, the top of the snowpack shows fewer counts near the surface and widely different counts among the three conditions. It is generally recognized that melt of a snowpack is mostly from the surface. The counts in the surface snow appear to be related to the delay in start of the snowpack melt and to the rate of melt of the pack after melt starts. This possibility of the gamma and neutron counts permitting prediction of snowmelt's contribution to streamflow deserves further exploring.

Plans--We plan to continue studies of the ability of radioactive probes to detect thermal quality of mountain snowpacks and characteristics of the snowpacks which dictate each year the amount of heat which will be required before ablation of the pack starts and the rate of melt of the pack after it starts.

Cooperation--The Atomic Energy Commission is cooperating by making funds available for many of these studies.

Andesite Experimental Watersheds (Study No. 1-24)

Two small, 30-acre experimental watersheds were established in the headwaters of the Castle Creek basin in September, 1962. Concrete cutoff walls with small debris storage basins and 120 degree V-Notch weirs characterize the installations. The watersheds were established with the intent of calibrating watersheds suitable for testing the effects of riparian treatment on savings of water.

Plans--Plans will depend on appraisal of the records.

ORGANIZATION

The organization of the California Cooperative Snow Management Research Program during the biennium 1961-62 and 1962-63 included these professional staff members:

Professional Staff

Anderson, Henry W.	O'Regan, William G.
Bowden, Kenneth L.	Richards, Lucille G.
Gay, Lloyd W.	Shumway, Clyde A.
Gleason, Clark H.	Wallis, James R.
Hopkins, Walt	West, Allan J.
Mansfield, Clifford W.	Willen, Donald W.
McDonald, Phillip M.	Ziemer, Robert R.
Miller, David H.	

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APPENDICES

A. TABLES

B. FIGURES

C. REPRINTS, selected 1962 and 1963 publications

APPENDIX A

TABLES 1 - 5

Table 1.--Meteorological, snow, and soil moisture records taken and status of data processing

STATION	ELEMENT	INSTRUMENT	FREQUENCY OF READINGS	PERIOD COVERED FROM	PERIOD COVERED TO	PROCESSING STATUS
H Headquarters CSSL	Precipitation	Recording gage	Continuous	12-4-56	6-30-63	Hourly tabulations made; published by U.S. Weather Bureau in "Hourly Precipitation Data."
	Snowfall	Snow Board	Daily, Winter season	10-31-56	6-30-63	Plotted, cumulatively.
	Snowpack	Mt. Rose snow sampler	Daily, 0800 Winter season	10-31-56	6-30-63	Plotted on graph.
	Air Temperature					
	Max. & Min.	Thermometers	Daily, 0800	10-1-56	6-30-63	Plotted on graph.
	Max. & Min.	Thermograph	Continuous	11-9-56	6-30-63	Not tabulated.
	Current	Thermometers	Daily, 0800	10-1-56	6-30-63	Not tabulated.
		Thermograph	Continuous	11-9-56	6-30-63	Not tabulated.
	Air Moisture	Psychrometer	Daily, 0800	10-1-56	6-30-63	Not tabulated.
	Air Moisture	Hygrograph	Continuous	11-9-56	6-30-63	Air moisture at time of max. temp. plotted on graph.
	Atmospheric Pressure	Merc. Barometer	Weekly	1-24-57	6-30-63	Not tabulated.
	Atmospheric Pressure	Barograph	Continuous	2-1-57	6-30-63	Not tabulated.

Table 1.--Continued

STATION	ELEMENT	INSTRUMENT	FREQUENCY OF READINGS	PERIOD COVERED FROM	PERIOD COVERED TO	PROCESSING STATUS
M Upper Meadow Castle Creek	Precipitation	Recording gage	Continuous	4-19-58	6-30-63	Not tabulated.
	Snowfall	Snow Board	Bi-weekly Winter season	10-31-56	6-30-63	Not tabulated.
	Snowpack	Mt. Rose snow sampler	Bi-weekly, Winter season	10-31-56	6-30-63	Tabulated, State reports.
	Air Temperature					
	Max. & Min.	Thermometers	Bi-weekly	12-26-56	6-30-60	Not tabulated.
	Max. & Min.	Thermograph	Continuous	12-26-56	1-4-60	Not tabulated.
	Air Moisture	Hygrograph	Continuous	12-26-56	1-4-60	Not tabulated.
O Onion Creek	Precipitation	Recording gage	Continuous	10-10-57	6-30-63	Not tabulated.
	Snowfall	Snow Board	Bi-weekly, Winter season	1-10-57	6-30-63	Not tabulated.
	Snowpack	Mt. Rose snow sampler	Bi-weekly, Winter season	1-10-57	6-30-63	Tabulated, State reports.
	Air Temperature					
	Max. & Min.	Thermometers	Bi-weekly	1-10-57	6-30-63	Not tabulated.
	Max. & Min.	Thermograph	Continuous	4-16-58	6-30-63	Not tabulated.
	Current	Thermograph	Continuous	4-16-58	6-30-63	Not tabulated.

Table 1.--Continued

STATION	ELEMENT	INSTRUMENT	FREQUENCY OF READINGS	PERIOD COVERED FROM	PERIOD COVERED TO	PROCESSING STATUS
O Onion Creek	Air Moisture	Hygrograph	Continuous	4-16-58	6-30-63	Not tabulated.
	Soil Moisture	Nuclear Probe and Scaler	Monthly, Summer season	8-7-58	10-12-61	Reported.
R Ridge	Snowfall	Snow Board	Monthly, Winter season	2-20-57	6-30-60	Not tabulated.
	Snowpack	Mt. Rose snow sampler	Monthly, Winter season	2-20-57	6-30-60	Not tabulated.
Blue Canyon	Precipitation	Recording gage (from W.B.)	Continuous	9-1-58	6-30-63)	Hourly Tabulation made by W. B. Combined into monthly summary
	Wind Speed and Direction	Esterline-Angus Recorder	Continuous	9-1-58	6-30-63)	
Wishon Dam	Air Temperature					
	Max. & Min.	Thermometers	Daily, 0745	12-5-56	6-30-63)	Checked and tabulated.
	Max. & Min.	Thermograph	Continuous	12-19-57	6-30-63)	Checked.
	Current	Thermometers	Daily, 0745	12-5-56	6-30-63)	Not tabulated.
	Current	Thermograph	Continuous	12-19-57	6-30-63)	Not tabulated.
	Air Moisture	Psychrometer	Daily, 0745	12-5-56	6-30-63)	Not tabulated.

Table 1.--Continued

STATION	ELEMENT	INSTRUMENT	FREQUENCY OF READINGS	PERIOD COVERED FROM	PERIOD COVERED TO	PROCESSING STATUS
	Air Moisture	Hygrograph	Continuous	12-19-57	6-30-63	Not tabulated.
	Wind miles	Anemometer	Daily, 0745	12-5-56	6-30-63	Not tabulated.
	Snow Evaporation	Snow Pans	Monthly, Winter season	1-24-57	6-30-61	Tabulated and summarized.
Swain Mt.	Snowpack	Mt. Rose snow sampler	Monthly, Winter season	1-6-58	6-30-61	Reported.
	Soil Moisture Data	Nuclear Probe and scaler	Monthly, Summer season	7-2-58	10-5-61	Reported.
Sagehen	Snowpack	Mt. Rose snow sampler	Monthly, Winter season	3-2-60	6-30-62	Summarized.
	Soil Moisture	Nuclear Probe and Scaler	Monthly, Summer season	7-24-58	8-29-62	Reported.
	Precipitation	Recording gage	Continuous	9-20-62	6-30-63	Tabulated.
Yuba Pass	Snowpack	Mt. Rose snow sampler	Monthly, Winter season	1-27-61	6-30-63	Summarized.
	Soil Moisture Data	Nuclear Probe and Scaler	Monthly, Summer season	10-28-60	6-30-61	Summarized.
	Precipitation	Storage gage	Monthly	11-6-62	6-30-63	Not tabulated.

Table 1.--Continued

STATION	ELEMENT	INSTRUMENT	FREQUENCY OF READINGS	PERIOD COVERED		PROCESSING STATUS
				FROM	TO	
Donner Ridge	Snowpack	Mt. Rose snow sampler	Monthly, Winter season	2-3-61	6-30-62	Not tabulated.
	Soil Moisture Data	Nuclear Probe and Scaler	Monthly, Summer season	9-1-61	6-30-62	Not tabulated.
Salmon Creek	Precipitation	Storage gage	Bi-monthly	12-1-60	6-30-63	Tabulated.

Table 2.--Central Sierra Snow Laboratory daily precipitation data 1961-62

Date	1961 July	Aug.	Sept.	Oct.	Nov.	Dec.	1962 Jan	Feb	Mar	Apr.	May	June
1						1.32			.72	.02		
2						.75			2.78			
3	.20					.24			.55			
4	.03											
5		.01							.10			
6		.03						.08	2.14			
7		.01						.98	.30			
8				T				1.34	.11			
9								2.51	.27			
10						.03		3.62	.03			
11				.09		.09		1.41	.77			
12				.17			.25	.30	.16			
13		.04					.33	1.05			.22	
14								1.74			.10	
15						.03		2.04			.22	.15
16					.11			2.46	.16		.97	
17			.67			.28		.72	.20		.01	
18			.22			.44	.10	T			.01	
19		.01				.42	1.72	.11				T
20		.04		.19	.93	.51	3.11	.29	.08	.53		
21				1.96	.25	.25	.64	.10	.15		.02	
22				.02	.19				2.20			
23					.06				.05			
24								1.60				
25								.11				
26				.55	.68	.04		.39			.07	
27		.03		.53	.13						.20	
28		.02		.98						1.53	.13	
29		.75		.04						.14		
30					2.99							
31									.02			
Sums	.23	.94	.89	4.53	5.34	4.40	6.15	20.85	10.79	2.22	1.95	.15

Total for Year -- 58.44

Table 2a.--Central Sierra Snow Laboratory daily precipitation data 1962-63

Date	1962: July	Aug.	Sept.	Oct.	Nov.	Dec.	1963: Jan.	Feb.	Mar.	Apr.	May	June
1								7.78		1.32		.04
2						.29		1.06	.19	.14		.03
3						1.65		.08	.01	.04	.02	
4							.13			.05	.08	.02
5								.39		.05		.03
6								.03		1.92		.40
7								.03	.40	2.28		
8								.04	.01	1.22		
9		.28						.01	.26	.44	.12	.01
10					1.08			.15	.02	.47	1.47	.40
11				2.10	.02				.01	.83	.30	
12	.35			4.73	.02						.83	
13				5.45				1.18			.14	.01
14				3.98	.18			.29	1.30	.35	.12	.08
15				.14	.02	.12			.33	2.46		.31
16					.17	1.92			1.24	1.19		.02
17					.08	.77		.13	.10	.03		.15
18						.33		.01		.24		.17
19					.02					1.23		
20										1.41		
21										.26		
22										.14		
23									1.90			.20
24									1.07			.07
25												
26			.12					.01		.01	.02	
27	T				2.15				.38	.08	.02	
28	.34		.06		.04		.04		3.97	.05	.45	
29			.10		.02		.40		.56		.71	.04
30							2.50		.30			
31							4.63		.06		.08	
Sums	.69	.28	.28	16.40	3.80	5.08	7.70	11.19	12.11	16.21	4.36	1.98

Total for Year -- 80.08

Table 3.--Monthly climatic summary, Central Sierra Snow Laboratory, 1961-62

Month	AIR TEMPERATURES							Total precipi-tation	Cum. daily snow w.e.	Month-end snow w.e. [1/]
	Averages			Extremes						
	Max.	Min.	Mean	Highest	Date	Lowest	Date			
1961	F°	F°	F°	F°		F°		----------inches	----------	----------
July	77.5	43.3	60.4	86	12,22	30	6	0.23	0.00	0.0
Aug.	73.0	44.7	58.8	86	4	36	16	0.94	0.00	0.0
Sept.	65.5	36.1	50.8	75	7	28	29	0.89	0.00	0.0
Oct.	55.7	31.1	43.4	74	3,4,15,16	17	28	4.53	1.92	0.0
Nov.	42.7	23.0	32.8	61	7	5	21	5.34	4.72	0.0
Dec.	36.7	16.2	26.4	52	24	-3	11	4.40	3.78	9.7
1962										
Jan.	38.0	15.8	26.9	57	31	-6	22	6.15	6.64	15.5
Feb.	34.5	17.8	26.2	55	1,3	-8	26	20.85	20.47	39.8
Mar.	35.5	13.9	24.7	52	29	3	10	10.79	11.97	50.5
Apr.	52.2	26.6	39.4	63	14,18	11	29	2.22	1.85	31.8
May	48.2	28.7	38.4	60	6	21	20	1.95	1.34	3.5
June	66.9	36.3	51.6	77	22,23	27	4,5	.15	0.00	0.0
Total								58.44	52.69	
Average	52.2	27.8	40.0							

1/ Water equivalent

Table 3a--Monthly climatic summary, Central Sierra Snow Laboratory, 1962-63

Month	AIR TEMPERATURES							Total precipi- tation	Cum. Daily snow w.e	Month-end snow w.e.[1]
	Averages			Extremes						
	Max.	Min.	Mean	Highest	Date	Lowest	Date			
1962	F°	F°	F°	F°		F°		---------inches	------------	
July	74.0	42.0	58.0	80	22,24	36	1	0.69	0.00	0.0
Aug.	72.7	42.0	57.4	84	16	32	29	0.28	0.00	0.0
Sept.	70.1	40.5	55.3	79	18	32	19	0.28	0.00	0.0
Oct.	56.2	33.2	44.7	75	1,2	26	5,14,16	16.40	1.35	0.0
Nov.	45.8	27.7	36.8	62	2	15	30	3.80	2.25	1.8
Dec.	42.1	23.6	32.8	53	11	7	26	5.08	1.37	1.8
1963										
Jan.	39.6	17.5	28.6	50	22,23,24,25	-2	12	7.70	3.64	6.8
Feb.	44.6	27.4	36.0	56	24,25	15	15	11.19	2.63	2.3
Mar.	38.1	19.5	28.8	52	21	5	18,24	12.11	10.54	11.2
Apr.	34.9	19.4	27.2	55	29	0	2	16.21	16.29	25.0
May	53.4	31.2	42.3	70	20	19	9	4.36	2.49	2.5
June	60.3	36.7	48.5	75	17	28	3,30	1.98	0.00	0.0
Total								80.08	40.56	
Average	52.6	30.1	41.4							

1/ Water equivalent

Table 4.--Land use and cover type in the "Sacramento River at Delta" watershed (1944 photography)

WATERSHED NAME AND LOCATION	STATE NUMBER	USGS NUMBER	NET AREA
Sacramento River at Delta	A21300	11-3420.00	427.00 sq. mi.

LAND USE CATEGORY	AREA PERCENT	AREA SQUARE MILES
Urban	0.56	2.38
Grass	0.42	1.79
Crop	0.07	0.30
Barren porous	4.78	20.41
Barren non-porous	6.92	29.56
Unlogged forest	44.61	190.50
Logged forest	1.46	6.25
Brush	39.73	169.66
Logged, now brush	0.00	0.00
Improved roads	0.77	3.28
Unimproved roads	0.28	1.19
Lakes, reservoirs	0.12	0.49
Stream channels	0.28	1.19
	100.00	427.00

LOGGING CATEGORY	AREA PERCENT	AREA SQUARE MILES
TYPE		
Logging - Type 1	1.46	6.25
Logging - Type 2	0.00	0.00
Logging - Type 3	0.00	0.00
Logging - Type 5	0.00	0.00
Logging - Type 6	0.00	0.00
Clearcut	0.00	0.00
Logged area, now barren	0.15	0.62

LAND USE CATEGORY	PREDOMINANT ASPECT	PREDOMINANT SLOPE PERCENT
Urban	Due South	0.0
Grass	South 31° East	3.0
Crop	Due North	0.0
Barren porous	South 1° East	40.0
Barren non-porous	South 82°East	73.0
Unlogged forest	South 89° East	29.0
Logged forest	Due North	20.0
Brush	South 19° East	24.0
Logged, now brush	-	-

Table 4.--Continued

COVER TYPE	MEAN DENSITY PERCENT
Trees of unlogged forest	31.0
Total cover of unlogged forest	66.0
Trees of logged forest	10.0
Total cover of logged forest	55.0
Undisturbed brush	85.0
Logged areas, now brush	0.0

Table 5.--Differences in soil moisture storage and loss associated with brush removal, Sagehen, F and G, 1958-1962 1/

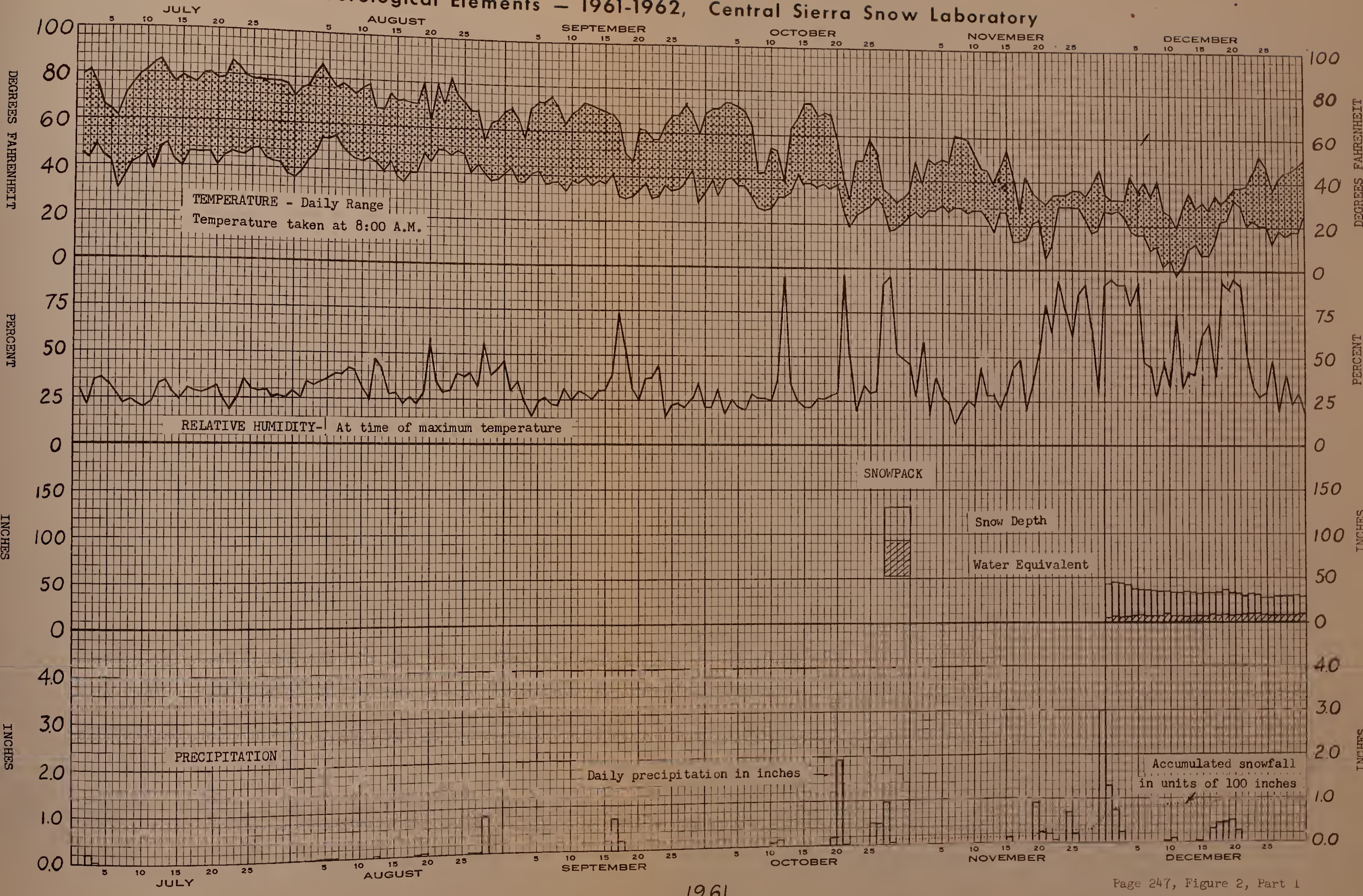
Date and treatment	Summer soil moisture storage for soil depths 2/ 3 feet	4 feet	5 feet
	----------Inches----------		
1958			
Cleared	11.3	15.9	20.6
Natural	7.8	11.6	15.6
Saving	3.5	4.3	5.0
1959			
Cleared	10.4	15.0	19.8
Natural	7.2	11.4	15.8
Saving	3.2	3.6	4.0
1960			
Cleared	9.3	13.7	18.5
Natural	7.1	11.0	14.7
Saving	2.2	2.7	3.8
1961			
Cleared	8.0	11.9	15.9
Natural	7.6	11.6	15.6
Saving	0.4	0.3	0.3
1962			
Cleared	7.5	10.8	14.7
Natural	7.6	11.7	14.7
Saving	-0.1	-0.9	0

1/ See paper 51 (p. 194) for site description.
2/ All for summer season 8/13 to 10/1, but same dates in each year for cleared and natural areas. Field moisture holding capacity is 12.5, 16.5, and 22.5 inches for the 3, 4, and 5 foot soils.

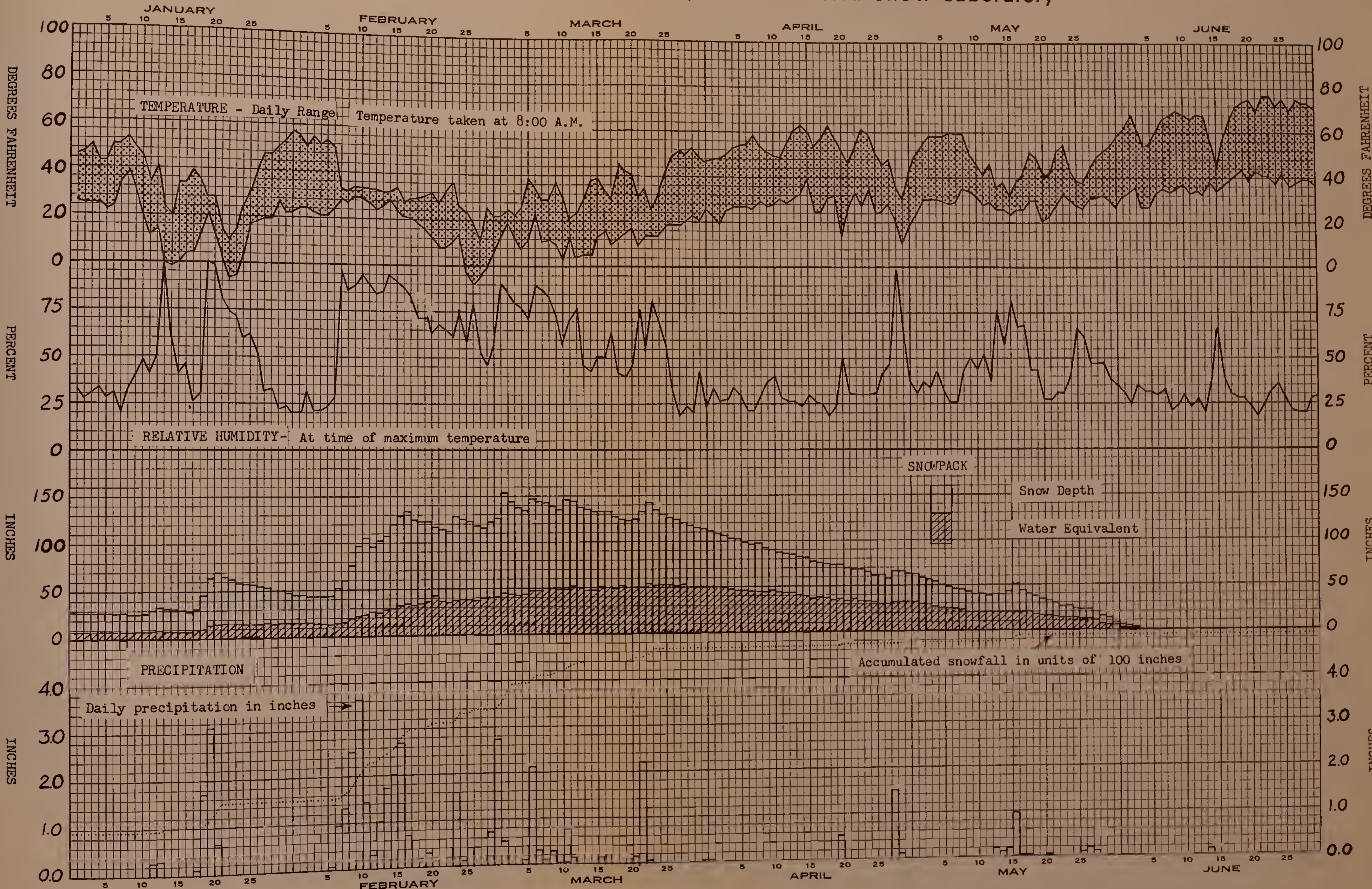
APPENDIX B

FIGURES 2 - 4

Synopsis of Hydrometeorological Elements — 1961-1962, Central Sierra Snow Laboratory

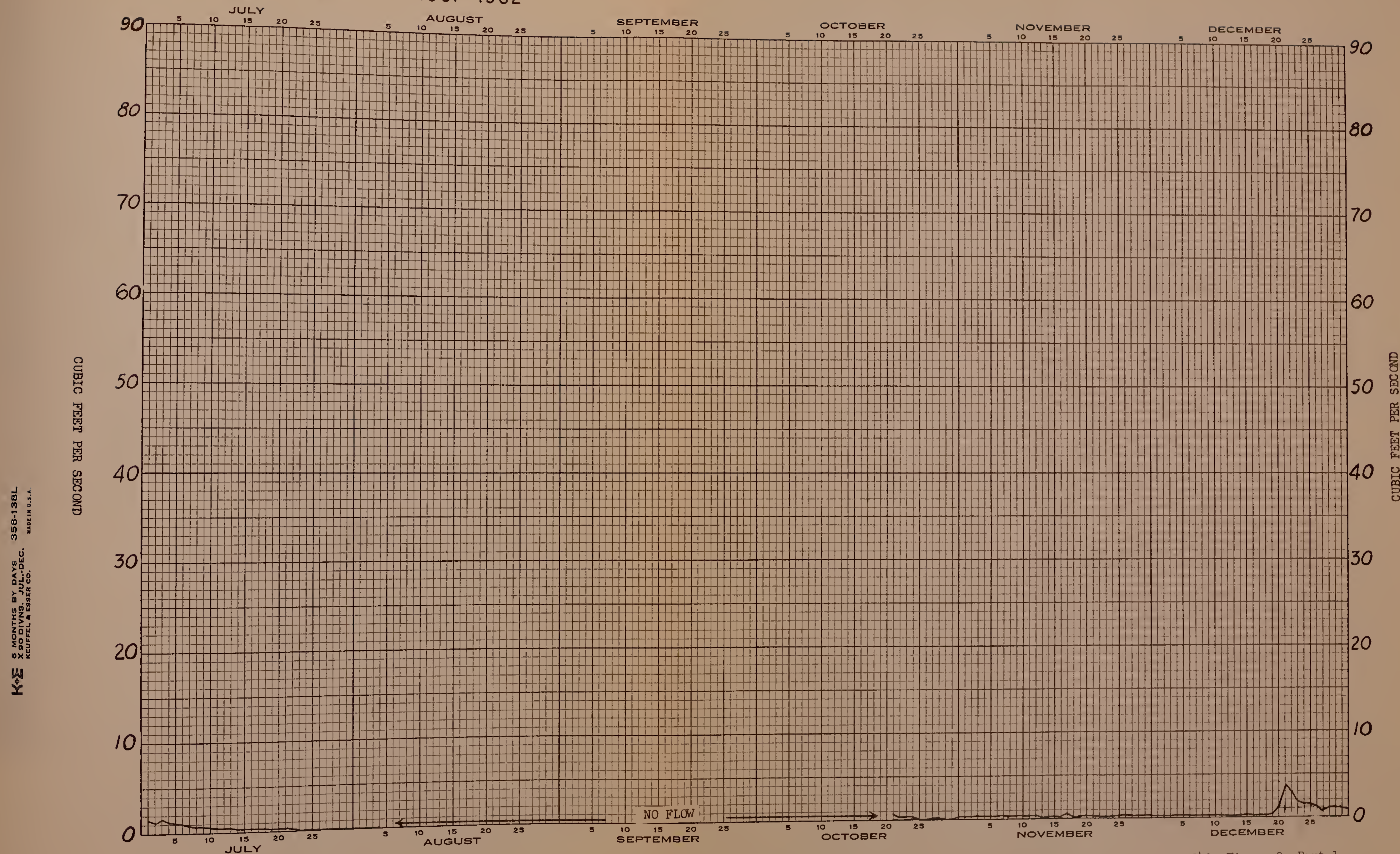


Synopsis of Hydrometeorological Elements — 1961-1962, Central Sierra Snow Laboratory



1962

Streamflow, Castle Creek - 1961-1962



Page 249, Figure 3, Part 1

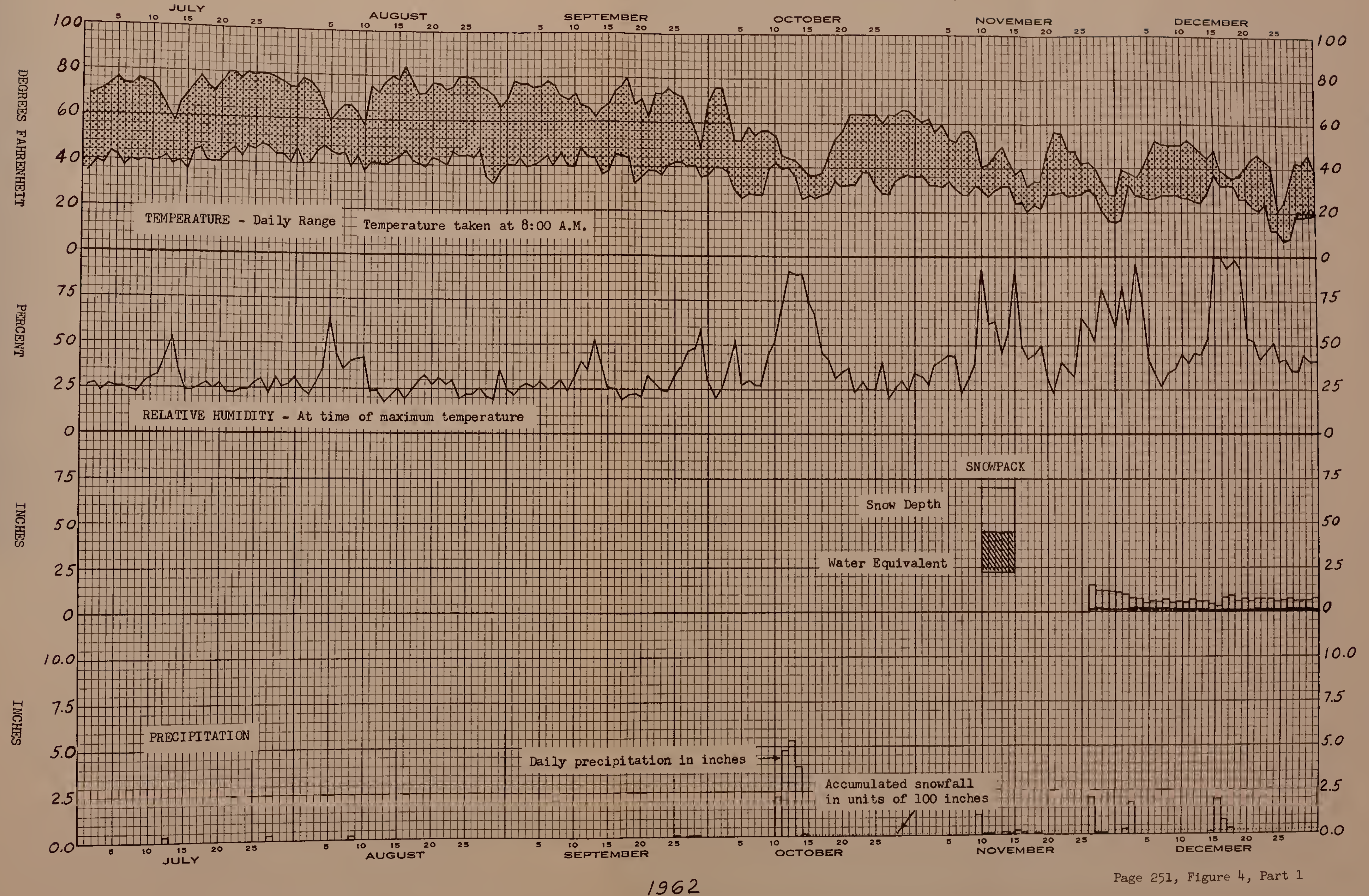
MEAN DAILY FLOW
1961

MEAN DAILY FLOW
1962

Page 250, Figure 3, Part 2

Synopsis of Hydrometeorological Elements - 1962 - 1963, Central Sierra Snow Laboratory

MG

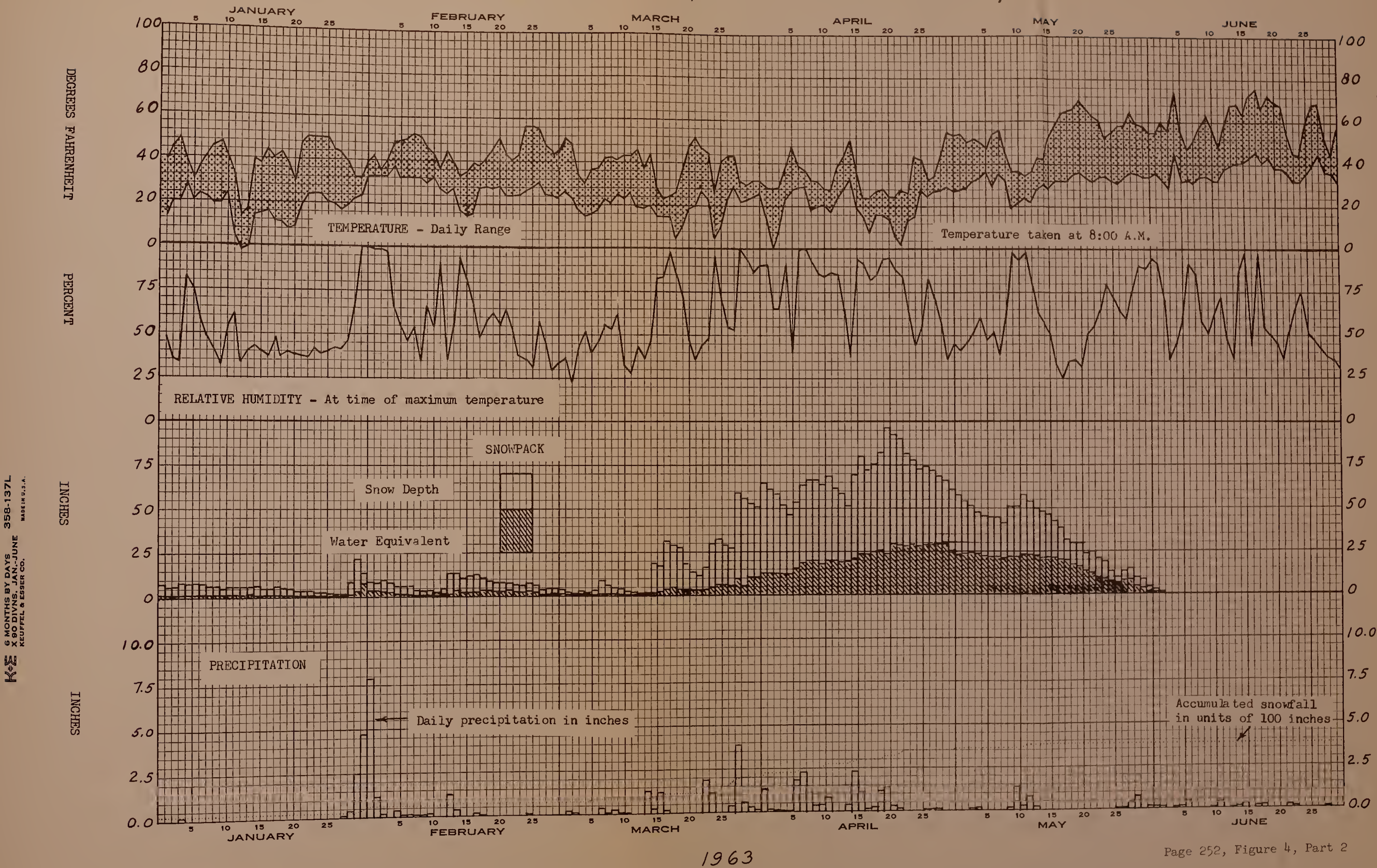


K+E 6 MONTHS BY DAYS X 90 DIVNS. JUL.-DEC. KEUFFEL & ESSER CO. 358-138L MADE IN U.S.A.

Page 251, Figure 4, Part 1

MG

Synopsis of Hydrometeorological Elements - 1962 - 1963, Central Sierra Snow Laboratory



APPENDIX C

REPRINTS